Arnold Schwarzenegger
Governor

COVELL VILLAGE: A MODEL FOR SUSTAINABLE COMMUNITIES

INDEPENDENT ASSESSMENT REPORT

Prepared For:
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Public Interest Energy Research Program
Energy Innovations Small Grants Program

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PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

PIER funding efforts focus on the following research, development, and demonstration (RD&D) program areas:

- Building End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Environmentally Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration
- Transportation
- Energy Innovations Small Grant Program

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million, five percent of which is allocated to the Energy Innovation Small Grant (EISG) Program. The EISG Program is administered by the San Diego State University Foundation through the California State University, under contract with the California Energy Commission.

The EISG Program conducts up to six solicitations a year and awards grants for promising proof-of-concept energy research.

The EISG Program Administrator prepares an Independent Assessment Report (IAR) on all completed grant projects. The IAR provides a concise summary and independent assessment of the grant project to provide the California Energy Commission and the general public with information that would assist in making subsequent funding decisions. The IAR is organized into the following sections:

- Introduction
- Project Objectives
- Project Outcomes (relative to objectives)
- Conclusions
- Recommendations
- Benefits to California
- Overall Technology Assessment
- Appendices
    - Appendix A: Final Report (under separate cover)

- Appendix B: Awardee Rebuttal to Independent Assessment (awardee option)

For more information on the EISG Program or to download a copy of the IAR, please visit the EISG program page on the California Energy Commission's website at: http://www.energy.ca.gov/research/innovations or contact the EISG Program Administrator at (619) 594-1049, or e-mail at: eisgp@energy.state.ca.us.

For more information on the overall PIER Program, please visit the California Energy Commission's website at http://www.energy.ca.gov/research/index.html.

Abstract

Combined Heat and Power (CHP) systems achieve efficient use of energy by effectively harvesting the waste heat from reciprocating engines, gas turbines, or steam turbine vapor cycles for heating and cooling purposes. Although common in Europe and other parts of the world, CHP systems are an emerging technology in the United States with significant energy and air quality benefits. This project evaluated the energy and economic potential of a CHP system for a proposed mixed-use development (2.78 million ft^2) in Davis, California. This largely residential project would include a CHP system to generate electricity and provide thermal energy (heating, cooling, and water heating) for the project.

A team of experts were assembled to evaluate the potential of the proposed Covell Village project. Key analyses were performed on the design, construction, and operation of cogeneration systems. A law firm specializing in energy issues provided a preliminary evaluation of issues surrounding ownership and operation of an energy facility in today's regulatory environment. Discussions were held with Pacific Gas and Electric Company to explore various ownership and utility grid interconnection issues.

A model was developed to evaluate aggregated loads, sizing of system components, and overall project energy and cost impacts. Various scenarios were developed to evaluate the impact of thermal loads on the system, as well as economically preferable models for system ownership and operation. Results indicate that the proposed system can significantly reduce load on the existing utility grid during peak periods and generate reductions in CO_2 and other emissions. The economics are marginally attractive to developers, and are enhanced significantly after accounting for avoided power network extension costs, increased grid supply security, and currently unvalued CO_2 emission reductions. The results clearly point to the need for state involvement in a project of this kind. With California as an international leader in energy and environmental issues, taking the lead on promoting sustainable communities of the future is essential to reap the broader economic and societal benefits that CHP systems offer.

Key Words: Combined Heat and Power, cogeneration, waste heat, Covell Village, sustainable communities, air quality.

Introduction

In the United States, a large percentage of electrical energy for buildings is supplied from centralized utilities. Distribution losses and lack of reuse of combustion products results in a relatively low utility delivery efficiency of 31.3 percent[1]. Inefficiencies in the system result in increased costs passed on to consumers, and increased pollutant emissions at the generation source.

To combat system inefficiencies, many European countries have begun providing energy to consumers through Combined Heat and Power (CHP) systems, also known as District Heating and Cooling. CHP systems are typically comprised of gas-engine-driven generators for generating electricity, heat recovery equipment for utilizing the waste engine heat, compression chillers and/or absorption chillers for providing chilled water for space cooling, and an underground network of pipes to deliver heating and cooling to the customers within the district (Figure1). Because CHP systems use a co-generation plant that is close to the end-users, combustion products including heat and steam can be recycled within the system, and the typical 8-9 percent distribution loss can be minimized, resulting in efficiencies roughly twice that of centralized utilities (~ 80 percent vs. 30 percent - 50 percent)[2]. With a CHP system, total residential energy usage could decrease from approximately11.90 kWh/ft^2 to 10.52 kWh/ft^2, and carbon emissions could reduce by 61 percent for a given demand. Additional benefits of a CHP system include improved system reliability and reduced reliance on the grid during peak usage periods which are typically charged at a premium.

The researcher proposed to assess the feasibility of implementing the CHP model within the Covell Village development in Davis, California. Covell Village consists of approximately 1,100 single-family homes, 300 multi-family units, and assorted commercial/retail space, totaling 2.78 million square feet of conditioned space. This village is well suited for district heating and cooling due to its relatively high density and large size. The CHP system would be located within Village Center retail/commercial portion of the site. Excess electric generation would be returned to the grid for credit, and deficiencies would be purchased from the grid, operated locally by Pacific Gas and Electric (PG&E). Peak demands are leveled using ice storage units which are charged at night and discharged mid-day. Analysis of the return on investment included the following components:

1) CHP system construction costs, projected at $25 Million. The principal investigator (PI) suggested that a $5,000 premium per house would be reasonable to offset the system cost.

2) Substitution of conventional heating, cooling and water heating equipment traditional water heaters with a District Energy service station, estimated at a $3,700 savings per house.

3) Energy production unit costs.

[1] U.S. DOE 2004
[2] Brown & Koomey, 2003

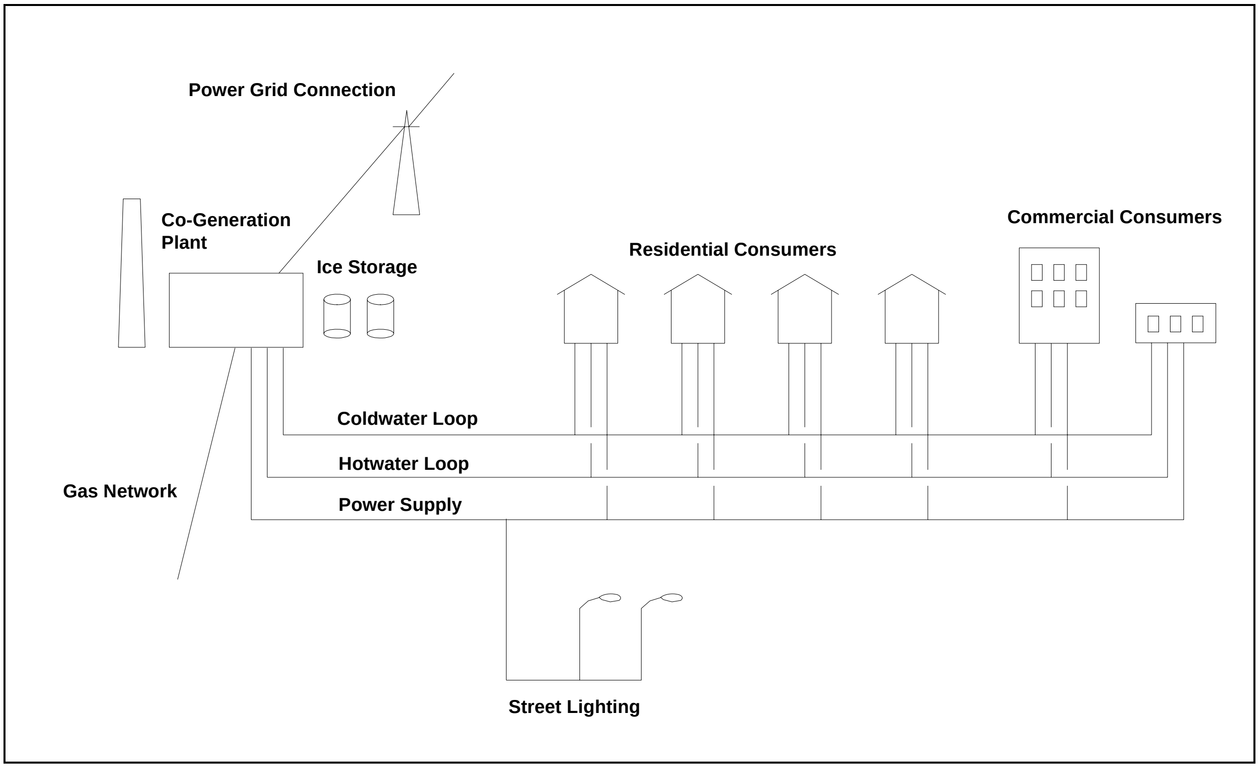

Figure 1: Schematic of a District Heating and Cooling System

Objectives

This project was to perform a preliminary CHP feasibility assessment for the Covell Village project. The researcher established the following project objectives:

1. Total residential energy use of less than 10 kWh_{elec}/ft^2 with electrical usage target of 4.5 kWk/ft^2-year (vs. 5.0 for Title 24 compliant house).
2. Home prices within 10 percent of conventional Title 24 homes.
3. Lower monthly mortgage payments, and lower monthly energy bills than the conventional Title 24 home.
4. CO_2 emission reductions of 40 percent or more relative to standard development.
5. Renewable energy sources that demonstrate a return on investment (ROI) of greater than 11 percent.
6. Proposed District Energy system has a projected ROI great than 11 percent.
7. District Energy System with super-efficient construction practices that will result in a projected ROI of greater than 11 percent.

Outcomes

1. Total base case residential energy use was estimated at11.90 kWh_{elec}/ft^2-year. Projected usage under the District Energy case was estimated at 10.52 kWh_{elec}/ft^2-year, falling short of the goal of 10 kWh_{elec}/ft^2-year. Failure to achieve this objective was attributed to difficulties in cost-effectively incorporating additional energy efficiency in conjunction with the CHP design.

2. Substitution of conventional heating, cooling and water heating equipment with a District Energy service station was projected to reduce “in house” costs by $3,700 per house. The researcher suggested that a portion of the $25 million District Energy system construction cost be borne by the homeowners, but conceded that the system would be cost prohibitive without public subsidy.
3. A savings of $3,700 per house translates into a $22 monthly mortgage reduction. A 10 percent reduction per month in thermal energy cost translates to approximately $6 per month, for a total savings of approximately $30 assuming a 30 year loan at 6 percent interest. This savings assumes that the homeowners will bear no portion of the District Energy system construction cost.
4. At build-out, projected carbon emission reductions will total 5480 metric tons per year, or 61 percent less than for conventional energy supply practice.
5. Solar water heating is not economically compatible with CHP due to the low marginal cost of utilizing engine waste heat generated by the CHP system. Solar electric similarly proved to be incompatible due to a larger unit cost than energy supplied through the District Energy system once installed. Economics of other sources, such as a biogas facility, were not quantified, but may prove to be synergistic.
6. Assuming PG&E operated the CHP system, annual costs were 6 percent lower than conventional energy supply with standard building practices. Note that this included a discounted personnel and administration cost which is not explained in the report.
7. Assuming PG&E operated the CHP system, annual costs were 9 percent lower than conventional energy supply with advanced building practices.

Conclusions

1. The objective to show total residential energy use of less than 10 kWh_{elec}/ft^2-year was not met. The researcher did not specify system improvements that would allow this objective to be met.
2. Although the base price of the house was not specified, the objective of keeping home prices within 10 percent of conventional Title 24 homes was met. According to the California Association of Realtors, the median home price in California was $538,770 in October 2005[3]; therefore, the objective would be met if the net system cost were less than $53,877. The principal investigator (PI)indicates a unit equipment cost savings per home of $3,700, assuming that the District Energy system would be subsidized in part if not in its entirety. Should public subsidy be unavailable, the cost per home for the District Energy system would be approximately $18,100. Reducing this by the equipment cost savings results in a net cost of $14,400 per home, still within the project objective. While the objective was met as written, the appropriateness of this objective may be questioned. Consumer acceptance of this premium will be a significant marketing challenge. Given the proximity of the co-generation plant to the residences, consumer acceptance will very likely be hindered by the same “not in my back yard” (NIMBY) issues that have plagued the utility industry in siting new power plants. These two factors alone may prove fatal to implementation of a CHP project. The concept that there is a market for homes at a premium price sited near a combustion-based power plant will require a very

[3] California Association of Realtors, 2005

significant marketing effort, and the existence of this market would seem to be part of the feasibility of this concept.

3. The objective to show a savings in monthly mortgage payments and monthly energy bills relative to conventional Title 24 homes can only be met with the assumption that the homeowner will bear no portion of the District Energy system cost. The likelihood or reasonableness of this assumption is not established in the report. The PI suggests that builders could charge homeowners a $5,000 premium over conventional pricing, with $8,700 per home remaining to offset the District Energy system cost. With this suggested premium, the mortgage payment increase would more than exceed any savings realized in monthly energy bills. Should subsidy be unavailable, the construction premium would need to be raised to $14,400, with a corresponding increase in monthly mortgage far surpassing the $6 monthly savings in utility costs.
4. The objective to reduce CO_2 emissions by 40 percent or more was met. The PI notes that although emissions would be reduced, they would be discharged to the community in which the end-users live. While it is reasonable to expect the community to be exposed to its energy impacts, it will further add to the marketing challenge and consumer acceptance.
5. The objective to show a ROI >11 percent for renewable energy sources was not met. Solar thermal and solar electric were either duplicative or detrimental to project cash flow.
6. The objective to show a ROI >11 percent for the district energy system under standard building practices was not met. The 6 percent ROI is sensitive to interest rates and fuel price escalation. Sensitivity studies in fuel and electricity price escalation indicate that CHP is less attractive with fuel cost increases, and more attractive with electricity cost increase. By assuming that both fuel and electricity would increase at similar rates, effects on the model are neutralized. The PI indicates that higher interest rates would weaken CHP economics and lower interest rates would improve them, however a sensitivity analysis was not presented. The ROI did not account for capital outlay for construction of the district energy system. Factoring in the district energy system cost, the simple payback period is in excess of 50 years, making this an unattractive investment.
7. The objective to show a ROI >11 percent for the district energy system under standard building practices was not met. The 9 percent ROI is sensitive to interest rates and fuel price escalation in a similar manner as described in item 6 above. Also, similar to item 6, this analysis did not include the capital outlay for the system. Incremental costs of implementing advanced energy-efficiency practices surpassed the incremental savings realized when combined with CHP. Therefore, it is not economically advantageous to exceed Title 24 energy-efficient building standards.

The original goal of the project was to perform a preliminary CHP feasibility assessment for the Covell Village project. This project is clearly not economically feasible. Few of the objectives were met as stated. From an economic perspective, the reasonableness of the expectation that the district energy system capital costs can be fully subsidized is critical, but is not established. Even with this assumption though, the return on investment makes the project only marginally attractive. Beyond economic acceptability is social and political acceptability. The researcher showed that CHP systems are incompatible with renewable energy sources, or improvements in energy-efficient building practices. While this certainly indicates room for advancement in cost-effectiveness and/or government subsidy for renewable energy sources and energy-efficient construction, the use of CHP as presented is contrary to the current regulatory focus on increasing energy efficiency, decreasing usage and minimizing our impact on the environment. Further, with a lower unit cost (resulting from a higher conversion efficiency), there is a risk that usage would increase as seen historically. Given the risks associated with this investment, a significant ROI premium over standard investment options would seem necessary to attract investment.

CHP is advantageous in terms of load management and grid reliability. Ice storage allows for better management of peak loads, which would provide for significant savings under a demand metering system. Grid reliability is also gained for consumers within the supplied district, as well as for those served only by traditional utilities as electricity can be transferred to and from the grid by the CHP system.

This study leaves some question as to who should own and operate the system. Although several owner and operator scenarios are discussed, the PI suggests that PG&E is the logical choice for system operator in spite of the fact that PG&E has not expressed an interest in serving as the owner. While it is true that PG&E is the prime beneficiary of the conversion efficiency and is capable of doing this task, there may be an opportunity for competitive bidding both in terms of cost of operation and also in terms of performance.

The potential applicability of this technology appears to be relatively low. The district energy approach is only feasible in large master-planned communities with high density. This includes approximately 10 percent of new homes built in California. The marginal project economics seen in Covell Village would be enhanced for projects in areas of extreme climate. This further reduces CHP's applicability as there are few areas within California characterized by extreme climates, and most of those are not likely candidates for high-density, large, master-planned communities. Significant infrastructure requirements for the district energy system appear to make retrofitting cost prohibitive. The low potential applicability for this technology may counteract efforts to secure public subsidy.

At present, there are too many unanswered questions regarding CHP acceptance, plant ownership, operation, and financing to conclude that application of CHP within Covell Village is feasible. Significant market and regulatory analysis will be required to resolve these issues.

Recommendations

The researcher should consider the following recommendations upon commencement of additional work in this area:

1. Conduct market analyses to identify:
    - Consumer acceptance (particularly in regards to NIMBY questions).
    - Maximum bearable construction premiums.
    - Scope and applicability of District Energy systems to California residents for economically feasible installations.
    - Parties interested in project ownership.
    - Parties interested in operating the CHP system.
2. Conduct a regulatory review to determine:

- Regulatory obstacles.
- Potential for subsidy of the CHP plant.

The CHP technology has significant obstacles to overcome in terms of economic viability and market acceptance. Efforts to overcome these obstacles will be required prior to resubmission for follow-on funding within the PIER program for assistance in full-scale field testing and commercialization.

Benefits to California

Public benefits derived from PIER research and development projects are assessed within the following context:

- Reduced environmental impacts of the California electricity supply or transmission or distribution system.
- Increased public safety of the California electricity system.
- Increased reliability of the California electricity system.
- Increased affordability of electricity in California.

The primary benefit to the ratepayer from this research is the improvement in the efficiency and reliability of the California electricity system. By bringing power generation to the end users, CHP systems can more efficiently use the combustion products and minimize the typically 8 – 9 percent transmission and distribution losses resulting in overall systems efficiencies roughly twice that of current central plant technology (~80 percent vs. 30 percent-50 percent). This conversion efficiency results in lower cost and pollutant emissions for a given demand. Interaction of the components within the co-generation CHP plant allow for better management of peak demand. Although the CHP plant is sized for the target community, it may exchange energy supply with the grid to supplement power in times of shortage/outage, or generate revenue by depositing surplus electricity. This exchange mechanism provides more reliability for customers within the CHP district, as well as those receiving power only from conventional utilities. Reliability for grid users would increase as more CHP plants were brought online.

Application of the high-efficiency CHP system would result in a 61 percent reduction in emitted pollutants with the following annual reduction estimates for Covell Village:

Table 1: Annual Pollutant Reductions for Covell Village

Pollutant	Annual Reduction (Metric Tons)
CO_2	5,480
SO_2	3,280
NO_X	10,770

These reductions presently have no financial value, but could become an asset in the future. For example, avoided carbon trades in the Kyoto countries trades of up to $10 per metric ton, translates to a yearly value of $54,800 for the Covell Village project[4].

[4] Point Carbon, 2005

Overall Technology Transition Assessment

As the basis for this assessment, the program administrator reviewed the researcher's overall development effort, which includes all activities related to a coordinated development effort, not just the work performed with EISG grant funds.

Marketing/Connection to the Market

The researcher has not yet developed a commercialization plan, but has identified a wide range of potential barriers including project ownership, utility involvement, metering issues, and regulatory issues.

Engineering/Technical

This project was not sufficient or successful in proving the feasibility of CHP implementation in Covell Village. Additional market and regulatory research is necessary to properly achieve this goal as described in the Recommendations section.

Legal/Contractual

This project does not include technologies that are patentable.

Environmental, Safety, Risk Assessments/ Quality Plans

Quality plans include reliability analysis, failure mode analysis, manufacturability, cost and maintainability analyses, hazard analysis, coordinated test plan, and product safety and environmental. Formal quality planning for this project is premature, but will need to address environmental risks relating to plant discharges in residential areas.

Production Readiness/Commercialization

This project is not yet ready for commercialization and will benefit from additional investigation into consumer acceptance and public/private funding opportunities.

Appendix A: Final Report (under separate cover)

Appendix B: Awardee Rebuttal to Independent Assessment (none submitted)

Attachment A – Grantee Report

COVELL VILLAGE: A MODEL FOR SUSTAINABLE COMMUNITIES

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Legal Notice

Acknowledgement Page

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Tandem Properties
Pacific Gas and Electric Company
Owens Corning
Garforth International, LLC
MVV Energie
Kirkpatrick and Lockhart

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ABSTRACT

Combined Heat and Power (CHP) systems achieve efficient use of energy by effectively harvesting the waste heat from reciprocating engines, gas turbines, or steam turbine vapor cycles for heating and cooling purposes. Although common in Europe and other parts of the world, CHP systems are an emerging technology in the United States with significant energy and air quality benefits. This project evaluated the energy and economic potential of a CHP system for a proposed mixed-use development (2.78 million ft^2) in Davis, California. This largely residential project would include a CHP system to generate electricity and provide thermal energy (heating, cooling, and water heating) for the project.

Davis Energy Group assembled an international team of experts to evaluate the potential of the proposed Covell Village project. Key analyses were performed by MVV Energie, a German firm specializing in the design, construction, and operation of cogeneration systems. Kirkpatrick and Lockhart LLP, a San Francisco law firm specializing in energy issues, provided a preliminary evaluation of issues surrounding ownership and operation of an energy facility in today's regulatory environment. Discussions were held with Pacific Gas and Electric Company to explore various ownership and utility grid interconnection issues.

MVV developed an EXCEL-based model to evaluate aggregated loads, sizing of system components, and overall project energy and cost impacts. Various scenarios were developed to evaluate the impact of thermal loads on the system, as well as economically preferable models for system ownership and operation. Results indicate that the proposed system can significantly reduce load on the existing utility grid during peak periods and generate reductions in CO_2 and other emissions. The economics are marginally attractive to developers, and are enhanced significantly after accounting for avoided power network extension costs, increased grid supply security, and currently unvalued CO_2 emission reductions. The results clearly point to the need for state involvement in a project of this kind. With California as an international leader in energy and environmental issues, taking the lead on promoting sustainable communities of the future is essential to reap the broader economic and societal benefits that CHP systems offer.

EXECUTIVE SUMMARY

Introduction

Most experts agree future worldwide energy consumption practices must change to avoid catastrophic consequences from global warming. With average U.S. utility delivery efficiencies of 31.3%[1], electric generation represents a prime target for improving fuel utilization and reducing greenhouse gas emissions. In many European countries, a significant percentage of annual electrical generation is provided by Combined Heat and Power (CHP) systems, which recover waste heat from the combustion process for subsequent utilization for space heating or other processes.

This EISG project evaluates the potential of a District Energy system in a residential community application. The Covell Village project in Davis, California, a proposed mixed-use development with approximately 1,500 residential units and 2.78 million square feet of conditioned floor area, was the basis for the evaluation of a plan that includes CHP coupled with a district heating and cooling network for delivering all electrical and thermal energy (in the form of heated or cooled water) to the entire project. By generating electricity, heating, and cooling onsite, the CHP project would significantly reduce the summer peak load demands on the state's existing utility grid infrastructure. In addition, the efficient fuel utilization characteristics of the CHP system would result in energy savings and air quality benefits (CO_2, SO_2 , and NO_X emission reductions).

Prime contractor Davis Energy Group, Inc. assembled an international team of experts to evaluate the issues surrounding the project. Team members include:

- MVV (a German firm with extensive world-wide experience in CHP)
- Garforth International, LLC (an international firm with a strong CHP background)
- Owens Corning, and
- Kirkpatrick and Lockhart (a San Francisco law firm specializing in energy issues)

Project Objectives

Specific quantifiable goals identified in the statement of work included demonstrating:

1. Total residential energy use less than 10 kWh_{elec}/ft^2 with electrical usage target of 4.5 kWh/ft^2-year (vs 5.0 for Title 24 compliant house).
2. Home prices within 10% of conventional Title 24 homes
3. Monthly mortgage payments plus monthly energy bill is less than conventional Title 24 homes
4. CO_2 emission reductions of 40% or more relative to standard development
5. Renewable energy sources demonstrate a return on investment (ROI) of > 11%
6. Proposed District Energy system has a projected ROI > 11%
7. Combining the proposed District Energy system with super-efficient construction practices result in a projected ROI > 11%

[1] DOE's August 2004 Building Energy Databook (Table 6.2.4.)

Project Outcomes

1. *Total energy use < 10 kWh_{elec}/ft^2 with electrical usage target of 4.5 kWh/ft^2-year*

Total base case residential energy use is estimated at 11.90 kWh_{elec}/ft^2-year, with 1.04 for cooling, 5.18 for heating, 2.93 for water heating, and the remainder due to miscellaneous electrical and gas consumption. Projected household usage under the District Energy case is estimated at 10.52 kWh_{elec}/ft^2-year, with 0.85 for cooling, 4.66 for heating, and 2.49 for water heating. The 10 kWh_{elec}/ft^2-year was not quite achieved due to difficulties in cost-effectively incorporating additional energy efficiency in conjunction with the CHP design.

2. *Home prices within 10% of conventional Title 24 homes*

Substitution of conventional heating, cooling, and water heating equipment with a District Energy service station is projected to reduce "in house" costs by $3,700 per house. The homeowners must bear a portion of the projected $25 million system cost, however for the project to be attractive in the marketplace some form of public subsidy is needed to ensure that costs are competitive and the societal benefits are recognized.

3. *Monthly mortgage payments plus monthly energy bill is less than Title 24 homes*

The estimated $3,700 lower cost translates to a $22 monthly mortgage reduction (assumed 30 year loan at 6% interest). Combined with a 10% discount on thermal energy (~$6 per month), homeowners should realize monthly cost savings of close to $30 with the District Energy system.

4. *CO_2 emission reductions of 40% or more relative to standard development*

At build-out, projected carbon emission reductions, based on today's mix of California electrical generation, would total 5,480 metric tons per year, or 61% less than would be the case with standard energy supply practice. The project will however negatively impact local air quality since the gas-driven engines will be located in Covell Village. From a sustainable development viewpoint it is reasonable to expect the community to be exposed to its energy impacts.

5. *Renewable energy sources demonstrate a return on investment (ROI) of > 11%*

Solar water heating is not economically compatible with CHP due to the low marginal cost of utilizing engine waste heat generated by the CHP system. We were unable to quantitatively evaluate the economic potential of using a proposed nearby biogas digester. Photovoltaic systems do create a synergy with District Energy systems since they help offset potential peak load purchases from the grid, however economic projections indicate a negative homeowner cash flow with electricity valued at an average District Energy rate of $.14 per kWh. Mandatory residential time of use metering and rates in the coming years will likely change this conclusion.

6. *Proposed District Energy system has a projected ROI > 11%*

In the absence of accounting for externalities, the proposed District Energy system does not achieve a ROI of 11% for the project developers. Emissions trading benefits, reduced utility generation, transmission, and distribution costs, and increased grid reliability, all represent significant benefits that cannot be accurately quantified for the key stakeholders (the State of California, electric utilities, developers, and homeowners) under the current regulatory framework.

7. *A District Energy system with super-efficient practices results in a ROI > 11%*

Analyses completed indicate that combining a District Energy system with super-efficient construction practices is counter productive. Once the District Energy system is installed, the marginal cost of delivering an incremental BTU of energy becomes very low, effectively doubling the payback of load reduction measures. One may arrive at a different conclusion in more severe climates or higher density developments.

Conclusions

1. The proposed CHP design integrates gas-fired engines, generators, boilers, absorption and mechanical chillers, and ice storage, to provide all energy needs for the project. When the project is fully built out (in 2014), projected "grid" peak demand savings are projected to be 3 to 4 MW (71% to 95% reduction), reducing the burden on California's power grid, decreasing natural gas consumption, and increasing power supply security. The proposed system is designed to complement the existing supply structure and allow electrical energy transfers to and from the Covell Village project.
2. Projected 2014 carbon emission impacts, based on the current mix of California electrical generation, are 61% less than with standard energy supply practice.
3. Approximately 50% of the projected CHP system cost is associated with the district heating and cooling piping network that delivers thermal energy from the central plant to end users. Higher load intensity increases the economic feasibility of a CHP system. "Demand side" energy efficiency measures decrease the energy intensity and therefore should be carefully evaluated.
4. There are no technical issues that present a significant challenge to the implementation of CHP at the Covell Village project. Under the assumed economic parameters, CHP is marginally cost effective. However, the on-site investment allows upstream investments in electricity generation, transmission, and distribution to be avoided. Once the full benefits are included, the returns for the Covell Village Energy System Operator are significantly better than for the PG&E system average. This indicates that PG&E probably would be a logical choice as system operator. Recognizing the limitations for PG&E to invest in an energy system of this type, the conclusion is that the system should be owned as a condominium asset of the entire Village.
5. The major barriers for the Covell Village project exist in defining who the system owner/operator is, what regulatory issues then come into play, and how the sale of BTU's will be handled. The limited funding under this project and the lack of certainty as to whether it would be built has prevented the project team from resolving the key issues with the developers, utility, and regulatory bodies. Given the significant long-term societal benefits of the proposed design approach, it is

recommended that the State of California take an active role in facilitating project implementation, coordinating regulatory issues (e.g. CPUC issue on selling of BTU's), encouraging utility cooperation, and reducing potential roadblocks.

Recommendations

1. Covell Village (or a similar project) should be positioned as a potential pilot development project for residential district energy. An investment grade Energy Master plan should be completed for this project.
2. Since California is the national leader in environmental and energy efficiency issues, the State should make the modest investment necessary to overcome any barriers for the developer and PG&E.
3. PG&E should serve as the operator for the Covell Village CHP system and Covell Village should be the cooperative owner of the energy assets. Although PG&E could also serve as the owner, they have not expressed an interest to do so.
4. Other higher energy intensity projects should be evaluated. A Sacramento redevelopment project (the Union Pacific Rail Yards) is currently under consideration.
5. Buildings in the Covell Village project should be built to a level of efficiency equal to the Title 24 Energy Standards. Exceeding Title 24 involves additional expense and reduces the cost effectiveness of the overall project.
6. Solutions should be established to allow a CHP District Energy system operator to economically benefit from avoided network and generation facility construction costs and from the reduced investments into supply security achieved by on-site power generation. In order to facilitate District Energy solutions based on CHP installations, the following measures should be considered:
    a. introducing a minimum guaranteed tariff of $.05/kWh for feeds of CHP-generated surplus electricity to PG&E's grids
    b. providing below market interest rates (5%) for long-term financing of CHP-based District Energy systems,
    c. introducing a heating and cooling network installation allowance fee or
    d. providing an initial grant to demonstrate political intention and to support market penetration.

Public Benefits to California

The proposed Covell Village district energy project offers significant value to California by increasing awareness of the technology as a future sustainable development path. Most forward-thinking planners agree that the nature of future development must move towards a more sustainable model with a reduced environmental footprint and less reliance on the centralized utility grid model.

Specific sustainable development elements that this project addresses includes:

<u>Greater energy efficiency</u>. The proposed CHP design would result in a significant improvement in energy efficiency relative to conventional practice.

Reduced impact on electrical grid. The proposed project would reduce summer peak electrical demand by 3 to 4 MW.

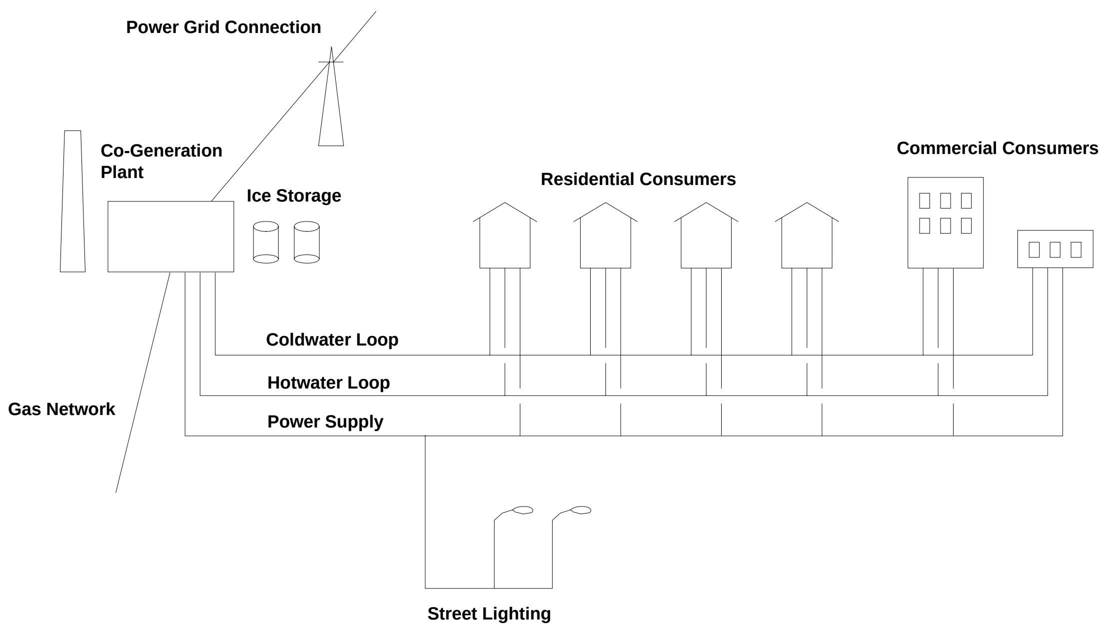
Reduced environmental impact. The proposed CHP design has significant environmental benefits include reduced air pollution and resultant global warming impacts.

Greater real estate affordability. Higher density construction implies smaller lots and smaller houses, contributing to lower home prices.

Introduction

A Combined Heat and Power (CHP) system is being considered by developers to meet the energy needs of a proposed mixed-use development in Davis, California. The project, encompassing approximately 1,100 single-family homes, 300 multi-family units, and assorted commercial/retail space, would have virtually all of its energy needs met by onsite generation. CHP (also known as district heating and cooling) systems are typically comprised of gas engine driven generators for generating electricity, heat recovery equipment for utilizing the engine waste heat, compression chillers and/or absorption chillers for providing chilled water for space cooling, and an underground network of piping to deliver heating and cooling to the customers within the project. Figure 1 depicts how such a system might be configured.

Figure 1: Generic Schematic of District Heating and Cooling System



This approach differs markedly from conventional practice where remote power plants generate electricity and dump waste heat to the environment via cooling towers or adjacent bodies of water. By bringing the power generation equipment to the end users, CHP installations can more efficiently utilize the combustion products and minimize the typical 8-9% transmission and distribution losses[2], resulting in overall systems efficiencies roughly twice that of current central plant technology (~ 80% vs. 30%-50%).

[2] Brown R. and J. Koomey, 2003. "Electricity Use in California: past trends and present usage patterns". Energy Policy

CHP systems are common in many parts of the world (including Europe) due to the confluence of many key factors over the last thirty years. Higher housing densities, greater environmental interest, and more favorable utility regulations allow for the sale of both “Btu’s” and electricity. Germany for example has a share of 10% co-generation in total electricity generation, and some countries, such as the Netherlands, have as high as 40%.

In the U.S., district heating and cooling exists in a limited scale in some university campus, industrial, and urban commercial applications, but not in a residential neighborhood project as proposed for the Covell Village development in Davis, California.

In general, CHP systems offer the following benefits:

- Increased overall efficiency of use of the primary fuel.
- Lower price volatility since fuel costs are a smaller fraction of operating costs.
- Improved financial productivity in terms of the capital efficiency in the use of generating plant.
- Reduced load on the existing electric generation and transmission infrastructure since the power plant is adjacent to the end use.
- Reduced environmental impact in terms of overall regulated emissions due to reduced fuel consumption.
- Substantially reduced greenhouse creation, mitigating impacts on climate change.

Due to the current lack of a greenhouse gas emissions trading scheme in the U.S., the last benefit does not have an immediate financial benefit. In the coming years this will probably change as reducing CO_2 emissions becomes a bigger national and international issue. In this report, greenhouse gas reductions or mitigation are assigned a zero financial value.

Figure 2 presents the current proposed layout of the 413 acre Covell Village project with single family housing located primarily on the northern half of the project (yellow area), senior and multi-family housing in the center of the project, and commercial space located in the southern sector (brown and orange). Proposed single-family housing densities are greater than for typical large subdivision developments in California[3]. The higher housing density is beneficial for the proposed district heating and cooling system since it increases the load on the connected distribution network per dollar of investment.

Davis, California is a fairly moderate climate with ASHRAE winter and summer design temperatures of 30°F and 100°F, respectively[4]. The bulk of the heating season runs from December through February with peak heating demand periods dominated by weather patterns with continual cold and foggy conditions. Spring and fall are mild with little or no space conditioning needs. Mid-summer is marked by hot dry weather with

[3] Although the project developers are seriously considering CHP, there are several issues, including a June 2005 city-wide referendum, which could affect project implementation.
[4] 2001 ASHRAE Fundamentals

temperatures frequently exceeding 95°F. Counteracting the daytime heat is a fairly consistent nocturnal Pacific sea breeze pattern that results in night cooling down to 60°F or below. With this type of summer weather pattern, the daily cooling loads are largely concentrated around a late afternoon peak.

Figure 2: Rendering of Proposed Covell Village Project

The overall goal of this project was to bring together a group of experts with varying specialties to perform a preliminary CHP feasibility assessment for the Covell Village project. While this report focuses on the evaluation and design efforts, a significant part of this project involved evaluating options for project ownership, utility interconnection, and regulatory/institutional issues that would impact the proposed project. These issues are complex and this study raises the issues and develops recommendations for removing some of the barriers to CHP development in California.

Project Objectives

Key objectives of this study are to:

- Demonstrate the energy savings potential that can be achieved at Covell Village at acceptable costs for the market, in conjunction with a CHP design.
- Demonstrate how Covell Village heating, cooling, hot water, and electrical needs can be met through 2020 with substantially reduced demand and emissions.
- Evaluate the potential for energy efficiency beyond code requirements and the use of renewable energy sources.
- Evaluate CHP technical and economic feasibility for the Covell Village project.
- Evaluate CHP scenarios and select the optimum basic system design.
- Indicate business, regulatory, code, and institutional changes needed to implement a community-wide, high performance energy system.

Specific quantifiable goals defined in the statement of work include demonstrating:

1. Total residential energy use less than 10 kWh_{elec}/ft^2 with electrical usage target of 4.5 kWh/ft^2-year (vs 5.0 for Title 24 compliant house).
2. Home prices within 10% of conventional Title 24 homes.
3. Monthly mortgage payments plus monthly energy bill is less than conventional Title 24 homes.
4. CO_2 emission reductions of 40% or more relative to standard development.
5. Renewable energy sources demonstrate a return on investment (ROI) of > 11%.
6. Proposed District Energy system has a projected ROI > 11%.
7. Combining the proposed District Energy system with super-efficient construction practices result in a projected ROI > 11%.

Project Approach

The project team includes:

- Davis Energy Group (a mechanical engineering consulting firm involved in innovative design and advanced HVAC product development)
- MVV (a German consulting firm with extensive world-wide experience evaluating, designing, and operating CHP systems)
- Garforth International, LLC (an international energy firm with a strong background in CHP) (match funding)
- Owens Corning (match funding)
- Kirkpatrick and Lockhart (a San Francisco law firm specializing in energy issues)

Prime contractor Davis Energy Group provided overall project management and technical services related to defining building energy use characteristics for the proposed development. MVV consultants had principal responsibility for evaluating and synthesizing the available data, and developing an EXCEL-based tool for sizing and evaluating various CHP system configurations. Peter Garforth was actively involved in optimizing system design and developing potential business models. Owens Corning provided technical support in terms of building component performance and cost effectiveness.

Thinking outside the box was a critical element of this project, since the proposed project is unique for the United States. Significant effort was expended in conceptualizing and comparing alternative business models, reviewing approaches with the local utility (PG&E), and analyzing legal issues and constraints. To facilitate this exchange, early in the evaluation phase the project team held a four-day planning session in Davis with all key members in attendance. During this session, meetings were held with the project developers, PG&E staff, and other parties. This planning session was instrumental in developing the framework for the analyses and resolving many of the complex issues surrounding a novel approach such as Covell Village.

Table 1 summarizes key project issues and efforts undertaken during the course of the project.

Assumptions and General Data

<u>Project Data</u>

The area enclosed within the Covell Village project area amounts to 413 acres with a proposed total conditioned floor area equal to about 2.78 million square feet. Although the actual project build-out is scheduled to occur over a seven-year period, for evaluation purposes we have assumed full build-out in one year. This is a simplifying but necessary assumption. It does result in slightly more optimistic economics, since energy use revenues occur in the same year as capital cost investments. Countering the optimism with the one-year build-out is the conservative assumption of fixed utility rates for the economic analyses.

Current assumptions on how the project will be developed is as follows:

- Single family homes: ~1100 units @ 2,000 ft^2 each (2,200,000 ft^2)
- Townhouses, lofts, co-housing: ~100 units @ 1,000 ft^2 each (100,000 ft^2)
- Multi-family homes: ~300 units @ 1,000 ft^2 each (300,000 ft^2)
- Commercial, administrative and retail facilities: (~180,000 ft^2)

Planning, investment and operation of a distributed energy supply must be carried out by an experienced energy supply company. Possible choices include a third party owner with the option of involvement of the customers, the project developer, or the City of Davis. Otherwise it would make sense that the local energy supplier (PG&E) develops the project as a new field of business and operates the facilities after installation.

Alternatively, PG&E could operate the system under contract to a third party owner. The advantages of a PG&E involvement are:

- Use of existing expertise for planning, installation, operation, and billing of energy services.
- The project can be embedded economically and technically in an existing system of supply of electricity and gas without experiencing energy cost surcharges .

Table 1: Summary of Key Project Actions

Technical Issues	Resolution
1. Develop standard case and improved case HVAC load estimates	DEG utilized a version of the MICROPAS simulation to model projected heating and cooling performance of the residential units. Since residential units represent 80% of the project conditioned floor area, they received the greatest emphasis. Other sources were used to generate typical commercial loads; hot water loads; and miscellaneous electrical loads[5].
2. Develop analytical tool	MVV modified an EXCEL spreadsheet to incorporate building load estimates, utility rate assumptions, and equipment performance assumptions, to develop and optimize CHP configurations for a variety of design alternatives.
3. Identify legal and regulatory issues	Kirkpatrick and Lockhart performed a preliminary review of possible ownership structures and potential regulatory issues to be addressed.
4. Business model	Extensive project team discussions (both internal and with PG&E representatives) were held to develop a desirable CHP business model.
5. Utility interactions	The project team met with PG&E staff to discuss issues related to potential ownership of the CHP system, energy transfers to and from the grid, and other interconnection issues. The PG&E position at this stage is one of interested observer. The novelty of the proposed approach and the uncertainty that it will come to fruition makes the lack of a definitive response from PG&E understandable.
6. Reporting	Documentation of project methodology, results, and recommendations.

<u>Load Assumptions</u>

1. Load projections are principally based on the California Building Energy Standards slated to take effect in October 2005. Although the build-out timeline

[5] PG&E, 1999. Commercial Building Survey Report.

(2007 – 2014) extends beyond the scope of the 2005 Standards, this assumption represents the best available data.

2. The load projections derived from MICROPAS modelling represent the energy demand of individual buildings. In order to achieve realistic system-wide load assumptions, coincidence factors are used. These factors incorporate diversity, recognizing that not all consumers impose load on the system at the same time.
3. It is assumed that additional heat demand occurs from pool heating at multi-family projects and a senior facility. Pool heating loads are a favorable end use for reclaimed engine waste heat.
4. In the district heating and cooling scenarios, street lighting is supplied from the installed generation facilities (street lighting represents a good base load and revenue source for the facility).
5. Since heating and domestic hot water are provided through the district heating system network, it is recommended that natural gas service not be provided to individual households. Elimination of natural gas supply to the project represents a sizable reduction in infrastructure costs. Propane tanks could be provided for those households who desire gas appliances (for cooking, fireplace, or outdoor barbeque). .

Assumptions Used in Calculating Project Economics

Table 2 summarizes key project assumptions relating to utility costs and interest rates for financing CHP equipment and infrastructure. For simplicity, no cost escalation was assumed in the utility rates resulting in conservative savings estimates for the CHP scenarios.

Table 2: Key Economic Assumptions

Parameter	Rate	Comments
PG&E electric rate (E-1)	$.14/kWh average	Standard case
PG&E gas rate (G-1)	$1.078/therm average	Standard case
PG&E street lighting tariff	$.09979/kWh	Revenue for CHP case
PG&E gas rate (large commercial)	$.809/therm average	Cost for CHP gas use
Grid energy transfers (to & from)	$.050/kWh average	Assumption based on PG&E as operator
Interest rate	5%	CHP project financing
Amortization Period	20 years	
Water costs	\$.86 per 100 ft^3	City of Davis costs
Wastewater costs	\$2.88 per 100 ft^3	City of Davis costs

Determine Covell Village Energy and Demand Needs

Davis Energy Group developed detailed heating and cooling load estimates using a version of the MICROPAS 2005 simulation model. The model represents performance requirements for the 2005 California Building Energy Standards, due to take effect October of 2005. These forward looking standards were used to better align baseline house performance with the anticipated 2007 to 2014 build-out period for the Covell

Village project. (As a necessary simplifying assumption in the analyses, we assumed that the entire project would come on line at one time.)

The 2005 Energy Standards[6] assume a fairly high level of energy efficiency relative to requirements in other parts of the United States. Low-leakage HVAC ducts, high performance (selective surface) windows, and high envelope insulation levels are strongly encouraged by the Standards. An element of this project was to evaluate how far beyond the Standards one could go while maintaining a cost effective district heating and cooling system.

The addition of cost effective energy efficiency technologies will save energy and reduce greenhouse gas emissions. On the other hand, the economic viability of various measures and packaging of measures are influenced by savings competition between measures. For this study we assumed two levels of energy efficiency options. The first "advanced building" option incorporates several low-cost measures such as third-party inspected "quality" wall and ceiling insulation installation, R-8 attic ducts, and optimised duct layout (minimizing the length of duct runs by moving supply registers from room exterior wall locations to interior wall locations). A second advanced building option incorporates the NightBreeze[7] night ventilation system, which integrates efficient night ventilation with the HVAC system control. In climates such as Davis, night ventilation can reduce annual household cooling energy use by roughly 50%.

Evaluation of Renewable Energy Sources

The main potential renewable energy sources considered in this project were solar electric (photovoltaic), solar thermal, and biogas (the product of fermented biomass). The installation of photovoltaic (or solar electric) systems is increasingly common in residential new construction, with improving economic feasibility due to available incentives and decreasing equipment prices. Use of photovoltaic power generation reduces project summer peak electric load and can provide favourable homeowner cash flows when coupled with a "time-of-use" utility rate structure. Projected costs and energy savings were obtained from an ongoing Building America project[8].

Solar water heating can help to decrease the heat demand for domestic hot water since a properly sized solar system can eliminate up to 50% of the energy use of a standard gas storage water heater. Unfortunately, solar water heating is not a particularly favourable match with a cogeneration plant. Although solar water heating significantly lowers hot water demand during afternoons and evenings from mid-spring to late fall, it has little beneficial impact on cold winter mornings when demand for heat and hot water is the greatest[9]. Comparing the costs, incentives and benefits of solar electric and solar

[6] The 2005 Standards will be in effect from October 2005 to mid-2008.
[7] http://www.energy.ca.gov/reports/500-04-009/500-04-009_ATTACH1.PDF
[8] Personal communication with Bill Dakin (January 2005)
[9] The winter design condition is critical in sizing the hot water distribution network. Any peak load reduction could contribute to a reduction in the cost of the piping network.

thermal technologies, solar electric is a better match with the proposed district heating and cooling system.

Use of biogas as fuel for energy generation is an interesting option for fuel diversification. It would have the features of using of local resources (primarily green waste), of saving fossil energy resources, and creating a further reduction of greenhouse gas emissions. Internal combustion engines using biogas or a mixture of biogas and natural gas are available as prime movers for power generation. Currently the City of Davis transports green waste to a neighbouring town at a cost of $28 per ton.

A planned project to install a 32 ton/day anaerobic digester for City of Davis could be combined with a possible co-generation project at Covell Village. The biogas digester is located at the Yolo County landfill, approximately 3-4 miles from the Covell Village project. A more detailed economic evaluation of biogas potential including land access issues should be undertaken if this project proceeds.

Evaluation of Alternative Energy Supply Scenarios

The following different scenarios were chosen for evaluation and comparison in this study.

- Standard scenario (conventional building practice with standard energy supply)
- Advanced building “1” (improved building characteristics, standard energy supply)
- Advanced building “2” (Advanced building “1” with NightBreeze)
- Local generation and distribution for standard buildings (standby power from grid)
- Local generation and distribution for advanced building “1” (with standby power from grid)
- Local generation and distribution for standard buildings (no standby power from grid)
- Local generation and distribution for advanced building “1” (no standby power from grid)

Evaluation of these scenarios was necessary to determine if district heating and cooling makes sense from an economic perspective given our best estimation of how the project would interface with the local utility (PG&E). This is a multi-dimensional complex issue that has been reviewed as part of this project and directional conclusions have been drawn. Given the novelty, and the hypothetical nature of the proposed project, PG&E has been unable to clearly define their position. If the project developers were to proceed with a district heating and cooling design, these issues would be resolved as the design process and business model is refined, as a part of the Final Energy Master Planning process.

The cost estimations for project implementation of distributed energy supply as well as standard scenarios include all costs necessary to meet the energy needs of all Covell Village customers. In addition to the variable costs (fuel and O&M), all required initial investments have been considered. Due to limited experience with community-wide CHP projects in the U.S., MVV primarily relied on their extensive database of cost information on comparable projects in Europe. Where appropriate, local costs were used to adjust or modify these European-based assumptions.

Description of the Standard Scenario
The standard scenario is the baseline for comparison for all other cases. This scenario assumes building construction practice consistent with the 2005 Energy Standards and connection to the existing PG&E electric and gas supply network. Space heating and cooling would be provided by a 78% AFUE gas-fired furnace and a 13 SEER split-system condensing unit. A 0.60 Energy Factor gas-fired storage gas water heater located in the garage of each dwelling unit would provide domestic hot water.

Description of the Advanced Building, Standard Energy Supply
This scenario adds the following building efficiency measures to the Standard scenario:

- Third-party field-verified "quality" insulation installation
- R-8 attic ducts
- Optimized duct layout (reduced length of duct runs)

Assumed building performance impacts include a 10% reduction in heating and cooling energy consumption.

Description of the Advanced Building with NightBreeze, Standard Energy Supply
This scenario is an upgrade of the prior scenario. The NightBreeze controls ventilation automatically and reduces "next day" cooling loads by use of nighttime ventilation. The annual cooling demand of single-family homes can be reduced by up to 50% by installation of this type of new technology.

Description of Local Generation and Distribution for Standard Buildings
This scenario includes the installation of all required equipment to generate and deliver electricity, hot and cold water for all consumers in the Covell village area. Appendix A provides three schematics of how key components of the district heating and cooling system would be configured. One schematic depicts the heat supply and distribution system, the second shows the cooling supply and distribution system, and the third shows the house service station, which delivers energy from the district network to individual dwelling units.

The cogeneration plant would be physically located within the Covell Village project area. The preferred location for the plant would be in an 8,500 ft^2 structure close to the PG&E main gas line and electric network. Installation of a medium voltage (MV) substation including switchboard and protection facilities as well as a gas metering and regulation station would be necessary, as would connection to water supply and wastewater disposal systems.

Since the economic feasibility of the project increases as additional load is added, it would be beneficial to connect neighboring customers to the Covell Village district heating and cooling system. The southeastern area shown in Figure 2 represents additional potential mixed-use development. In addition, nearby city and health club pools could become viable extensions of the network. These possibilities have not been factored into the calculations, but can be viewed as opportunities for marginally improving the overall project economics.

The cogeneration plant is sized to meet the peak thermal load. This approach results in a system undersized for peak electrical demand, but optimally sized for thermal needs. During peak electrical load periods, the Covell Village would be a net importer of electricity from the grid. During off-peak hours, Covell Village (with PG&E as operator) would export power to the grid. To properly handle load variations and routine repair/maintenance, several cogeneration units would need to be installed. The preferred cogeneration system type is a gas-fired internal combustion engine, due to the availability of natural gas and the low exhaust gas emissions. MVV estimates an electric efficiency of 37% can be expected for the required range of capacity. The electric and heat capacity of cogeneration units are related by a fixed ratio with typical power-to-heat ratios ranging from 0.6 to 0.9. The thermal capacity for the chosen engines is approximately 3,477 kBtu/hour per unit. This thermal capacity is sufficient to supply approximately 5,000 hours per year at full load from the co-generation units. Peak load boilers would be installed to meet excess load. Although variations of this basic CHP design exist, MVV considers the proposed design to be appropriate for the Covell Village project.

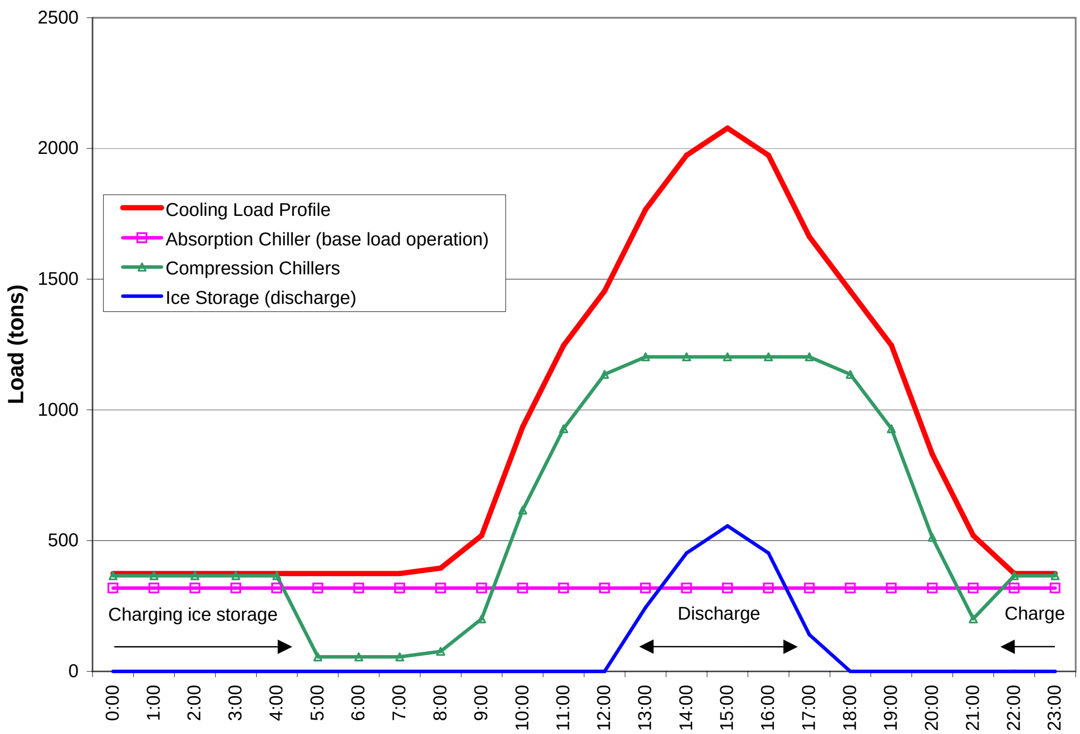
The preliminary scheme “Heat supply: Generation and Distribution” in Appendix A presents a schematic of the proposed design configuration. Absorption chillers represent an important consumer of excess heat during summer months when heating needs are significantly reduced. Comparable in efficiency to electrical chillers in a stand-alone sense, absorption chillers are highly attractive as a base load cooling system when “free” waste heat from the CHP system is available.

High peak loads drive the project-wide cooling demand, like the rest of California’s buildings. This dominates the design of the cogeneration plant. In order to decrease electricity demand for cooling from the grid, absorption chillers meet a significant part of the cooling load. The absorption chiller would utilize heat from the cogeneration plant, which during the cooling season would otherwise be wasted. Turbo-type water chillers would provide additional cooling capacity. Peak cooling load would be reduced by the use of an ice storage system. The ice storage system would be “charged” at night, when cooling demand is low and unloaded during late afternoon peak cooling periods. An additional screw type chiller, separated from the cold-water loop, would be needed to charge the ice storage system. Ice storage and screw chillers operate in an antifreeze loop separated by a heat exchanger from the cold water loop. Appendix A shows a generic representation of the cooling plant configuration.

The absorption chiller will cover the base load and be operated as much as possible. Figure 3 provides a representation of peak day operating patterns for the absorption chiller, compression chillers, and ice storage system. The net effect of the proposed system operation is to generate a much flatter cooling load profile allowing for absorption chiller and ice storage "charging" operation during the night and reduced compression chiller operation during the mid-day period.

The preliminary design has hot water and cold-water district loops separated into three lines in order to keep pipe diameters smaller and to allow for sufficient pump control. Each end-user on the district loop would have a house "service station" for hot and cold water supply to the units (see schematic in Appendix A - "House Service Station"). The service station provides heat exchangers, metering devices, a small tank for domestic hot water, and controls for transferring energy from the district loops to individual end users. From the service station, hot or chilled water would be delivered to a hydronic fan coil unit that replaces the standard furnace/split system air conditioner. The service stations would be pre-fabricated to simplify the installation process and could occupy the space normally used by the storage gas water heater.

Figure 3: Peak Day Projected Cooling Load Profile



Project Outcomes

The project outcomes are strongly affected by factors that in many cases cannot be adequately quantified given available data sources. However it is clear that District Energy systems with CHP offer significant societal and economic benefits that are not valued in the current model. These include:

- Significant reductions in the emissions of CO_2, SO_2, and NO_X
- Significant reductions in the use of natural gas
- Reductions in the need to upgrade transmission and distribution infrastructure
- Reduced need to build future centralized power generation facilities
- Improved reliability of the utility grid

Brief responses to the quantified goals identified in Objectives are presented here with further detailed information following.

Total residential energy use less than 10 kWh_{elec}/ft^2 with electrical usage target of 4.5 kWh/ft^2-year (vs 5.0 for Title 24 compliant house)

Total base case residential energy use is estimated at 11.90 kWh_{elec}/ft^2-year, with 1.04 for cooling, 5.18 for heating, 2.93 for water heating, and the remainder due to miscellaneous electrical and gas consumption. Projected household usage under the District Energy case is estimated at 10.52 kWh_{elec}/ft^2-year, with 0.85 for cooling, 4.66 for heating, and 2.49 for water heating. The 10 kWh_{elec}/ft^2-year was not quite achieved due to difficulties in cost-effectively incorporating additional energy efficiency in conjunction with the CHP design.

Home prices within 10% of conventional Title 24 homes

Substitution of conventional heating, cooling, and water heating equipment with a District Energy service station is projected to reduce "in house" costs by $3,700 per house. The homeowners must bear a portion of the projected $25 million District Energy system cost, however for the project to be attractive in the marketplace some form of public subsidy is needed to ensure that costs are competitive and the societal benefits are recognized.

Monthly mortgage payments plus monthly energy bill is less than conventional Title 24 homes

The estimated $3,700 lower cost translates to a $22 monthly mortgage reduction (assumed 30 year loan at 6% interest). Combined with a 10% discount on thermal energy (~$6 per month), homeowners should realize monthly cost savings of close to $30 with the District Energy system.

CO_2 emission reductions of 40% or more relative to standard development

At build-out, projected carbon emission reductions, based on today's mix of California electrical generation, will total 5,480 metric tons per year, or 61% less than would be the case with standard energy supply practice. The project will however impact local emissions since the gas-driven engines will be located in Covell Village. From a sustainable development viewpoint it is reasonable to expect the community to be exposed to its energy impacts.

Renewable energy sources demonstrate a return on investment (ROI) of > 11%

Solar water heating is not economically compatible with CHP due to the low marginal cost of utilizing engine waste heat generated by the CHP system. We were unable to quantitatively evaluate the economic potential of using a proposed nearby biogas digester. Photovoltaic systems do create a synergy with District Energy systems since they help offset potential peak load purchases from the grid, however economic projections indicate a negative homeowner cash flow with electricity valued at an average District Energy rate of $.14 per kWh. Mandatory residential time of use metering and rates in the coming years will likely change this conclusion.

Proposed District Energy system has a projected ROI > 11%

In the absence of accounting for externalities, the proposed District Energy system does not achieve a ROI of 11% for the project developers. Emissions trading benefits, reduced utility generation, transmission, and distribution costs, and increased grid reliability, all represent significant benefits that cannot be accurately quantified for the key stakeholders (the State of California, electric utilities, developers, and homeowners) under the current regulatory framework.

Combining the proposed District Energy system with super-efficient construction practices result in a projected ROI > 11%

Analyses completed indicate that combining a District Energy system with super-efficient construction practices is counter productive. Once the District Energy system is installed, the marginal cost of delivering an incremental BTU of energy becomes very low, effectively doubling the payback of load reduction measures. One may arrive at a different conclusion in more severe climates or higher density developments.

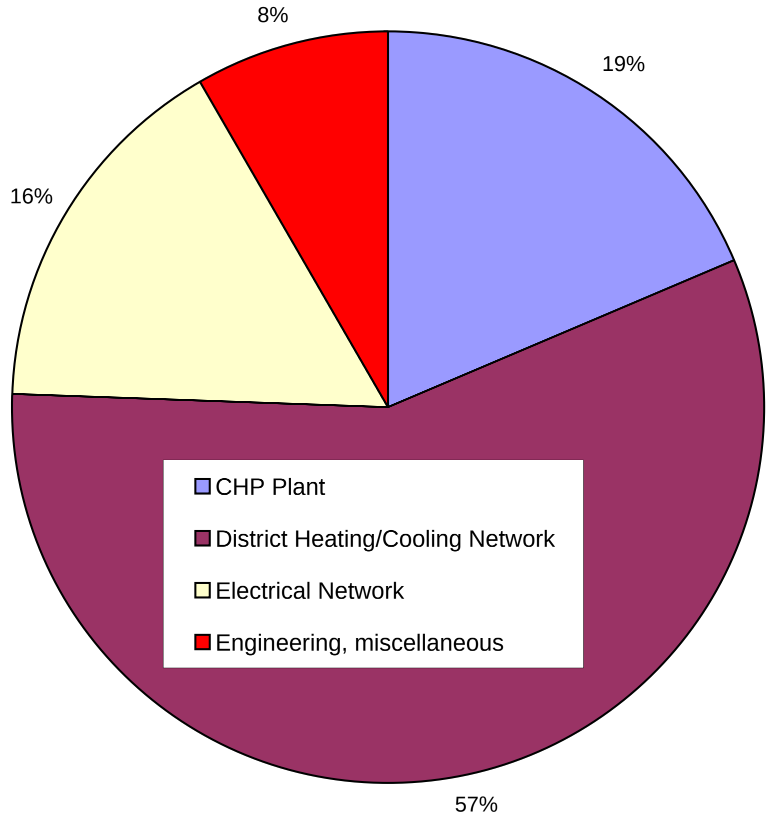
<u>Information Supporting Project Outcomes</u>

To simplify the presentation of results, all but the key summary results are presented in Appendices. Appendix B contains the energy use load estimates input into the MVV evaluation spreadsheet. Appendix C contains the input and output data from the MVV evaluation model including tables of calculations of demand patterns, design calculations, cost estimations, energy flows, and total annual costs for the supply of all customers of Covell Village.

A key aspect of evaluating and understanding the economics of the proposed Covell Village CHP design is how projected costs are distributed. Figure 4 presents a pie chart depicting project costs in four primary areas: the physical plant, the district heating and cooling network, the electrical network, and engineering and commissioning costs. What is most evident is the magnitude of the district heating and cooling network, representing over half of the project cost. With such a significant investment in the network, the obvious goal is to put as much load on the system as possible. This can be accomplished by some combination of the following factors:

- high housing density (more load per foot of network piping)
- project mix with more commercial floor area than residential (higher energy intensity)
- project location in a severe climate (higher loads)
- high utility costs (the CHP concept generates more value at higher fuel costs)
- optimizing, rather than maximizing energy efficiency (efficiency reduces loads)

Figure 4: Estimated Breakdown of Project Costs



Total annual costs for each of the described scenarios were calculated. For the co-generation scenarios, total annual costs have been calculated two ways: one assuming operation by a third party investor, and a second assuming operation by PG&E.

The total annual costs are comprised of the following types of costs:

- Annualized project capital cost (twenty year time line)
- Annual fuel cost (current rate assumptions)
- Cost for additional electricity supply
- Cost of personnel and administration

- Cost of repair and maintenance
- Other costs (engineering, etc).

Descriptions of key CHP equipment components are listed in Table 3.

Table 3: Key CHP System Components

Equipment Description	Nominal Performance
Two gas-fired engine modules (4.26 MBTU/hour thermal and 968 kW electricity each)	electric efficiency 38%, total efficiency 88%
One 320 ton hot water driven absorption chiller (42.8°F/ 53.6°F)	0.68 COP
Two 450 ton turbo-type compression chillers (42.8°F/ 53.6°F)	5.6 COP
One 450 ton screw-type compression chiller (23°F / 32°F) for ice storage charging	3.1 COP
33,000 gallon ice storage tank	
Two 15 MBtu/hour gas fired hot water peak load boilers (194°F /158°F)	92% efficiency

Table 4 summarizes the annualised economics of the cases evaluated. The three leftmost columns present base case construction practice under three scenarios: standard (complying with the 2005 Energy Standards), advanced building (efficiency improvements beyond Title 24), and advanced building with NightBreeze. The three columns on the right depict the CHP cases for standard building, advanced building, and advanced building with PG&E as the operator. The advanced building CHP case with PG&E as the operator offers the best economics through a combination of reduced electric costs (assumes wholesale instead of retail rates for electrical energy transfers to and from the grid) and reduced personnel and administration costs. The net annual cost advantage for the advanced building CHP case with PG&E as operator is projected to range from $147,000 to $380,000.

The proposed CHP design will integrate gas-fired engines, generators, boilers, absorption and mechanical chillers, and ice storage, to provide all energy needs for the project. Hot water (for space heating and water heating) and chilled water will be delivered to each customer. When the project is fully built out, projected "grid" demand savings are projected to be 3 to 4 MW.

The CHP system is projected to provide 65% of the total project heat demand (46,265 million Btu's). This recovered energy represents energy that does not have to be generated by burning natural gas in furnaces and water heaters located in individual houses. Chilled water generated by absorption chillers (from recovered CHP waste heat) is projected to save 2,522 MWH annually, or 20.6% of the total electricity demand. Additional savings are expected from higher efficiencies of the central chillers relative to the conventional distributed air conditioner condensing units.

Under the assumed economic parameters, CHP is marginally cost effective. With PG&E as operator, annual costs are 6% (~$255,000) and 9% (~$375,000) lower than conventional practice with standard and advanced building assumptions. Higher interest rates would weaken CHP economics and lower interest rates would improve them.

Various design configurations were evaluated to assess the most favorable CHP economic scenario. Despite our intent to incorporate additional energy efficiency into the Covell Village CHP project, the realities of the economics directed us to avoid additional expenditures in energy efficiency. This is because with the district heating and cooling infrastructure in place, there is an economic incentive to maximize the load on the system. The optimal design is based on sizing the CHP system for thermal load, utilizing absorption chilling for base load cooling, and ice storage for on-peak load shaving. This preferred configuration with PG&E acting as system operator was found to have an annual cost savings of $254,700 relative to standard construction practice and $147,100 relative to CHP standard building design with third-party owner/operators.

Table 4: Economic Comparison of Base Case and CHP Design Options

	Standard Building	Advanced Building	Advanced Building with NightBreeze	Standard Building with CHP	Advanced Building with CHP	Standard Building with CHP and PG&E Operator
Total Project Cost	$10,940,500	$12,867,780	$15,097,780	$23,877,835	$25,301,241	$23,877,835
Annual capital cost	$1,032,706	$1,214,627	$1,425,124	$1,916,019	$2,030,237	$1,916,019
Annual fuel costs	$1,057,014	$995,304	$995,304	$1,616,738	$1,585,359	$1,569,641
Electricity supply costs	$1,706,054	$1,706,054	$1,474,292	$0	$0	$0
Cost of personnal and administration	$0	$0	$0	$400,000	$400,000	$300,000
Cost of repair & maintenance	$113,886	$113,886	$140,646	$286,534	$303,615	$286,534
Other costs	$72,612	$72,612	$72,612	$9,044	$8,450	$9,044
Revenues (street lighting, grid sales)	$0	$0	$0	$353,640	$371,174	$353,640
Total	**$3,982,272**	**$4,102,484**	**$4,107,978**	**$3,874,696**	**$3,956,488**	**$3,727,598**
Annual cost increment relative to the best scenario	$254,674	$374,886	$380,380	$147,098	$228,889	$0

Photovoltaic systems have less favorable economics in the District Energy case than in current standard construction where time-of-use electric rates greatly enhance the value of generated electricity. In the District Energy case, electric rates are assumed to be constant ($.14 per kWh). Based on current data from an ongoing Davis Energy Group Building America project, a typical 2.4 kW system is projected to generate 3,469 kWh per year at an installed cost to the homeowner of $14,300. The annual homeowner savings of $485 results in a 30-year simple payback, or a negative cash flow of $45 per month (at 6% interest, 30 year loan, and ignoring tax implications).

Environmental Impacts

A primary benefit of CHP technology is reduced greenhouse gas emissions. Unfortunately there is presently no mechanism to value reduced carbon emissions in the USA. Energy related emissions in the standard scenario occur during power generation for the mix of power supplied to California[10], as well as from the combustion byproducts from furnaces and gas storage water heaters located at each residence. To quantify the potential impact of a CHP system at Covell Village, total annual energy related greenhouse gas emissions were compared for the "standard scenario" and the most advantageous cogeneration scenario.

The estimated annual CO_2 emissions related to energy supply in the standard scenario amounts to approximately 9,025 metric tons compared to 3,545 metric tons annually in the cogeneration scenario (61% reduction, or 5,480 metric tons). With California's relatively favourable mix of power generation (633 lbs of CO_2 per MWH generated[11]), CO_2 reductions are less significant than if viewed from a national perspective. National average CO_2 emissions of 1392 lbs per MWH, would increase the CO_2 savings from 5,480 metric tons annually to 12,054 metric tons. Projected SO_2 and NO_x annual savings for the full project are estimated at 3,280 lbs and 10,770 lbs, respectively.

Identification of Business, Regulatory, and Code Issues

District energy systems in residential applications are virtually unknown in this country, resulting in business barriers for early adopters. The primary barrier revolves around the issue of the ownership structure. Kirkpatrick and Lockhart presented the following three potential ownership structures as part of the initial legal review:

1. Ownership through the Covell Village Homeowners Association
2. Ownership by the local regulated utility (PG&E)
3. Third party ownership

Any of these three potential owners could conceivably operate the system, but the most logical choice would be either the utility or third party operation.

The delivery of energy to consumers is covered by the rules of the California Public Utilities Commission (CPUC), which has limited provisions for the delivery of thermal energy and for the integration of cogeneration within the electricity network. The CPUC has shown flexibility to small-scale cogeneration, including waiving stand-by charges. The energy service operator of the system will likely be an electric utility and fall under the rules of the CPUC. The same operator will also be delivering heating and cooling energy to the network, and the regulatory framework is uncertain and needs to be clarified, including the rights of the operator to set prices for heating and cooling energy.

Conclusions

Conclusion 1 Peak Electrical Demand

[10] See http://www.energy.ca.gov/electricity/gross_system_power.html for the following breakdown of energy sources for California: Coal (21.3%), large hydro (16.2%), natural gas (36.9%), nuclear (15.2%), and renewables (10.4%).
[11] See http://www.epa.gov/cleanenergy/egrid/pdfs/state.pdf

There is a major reduction in the peak electrical demand from the wider utility grid due to the use of recovered heat driving absorption chilling and providing base-load chilling. The "standard building base case" community wide peak demand is estimated at 4.2 MW. With CHP, typical summer on-peak grid demand will be less than 0.2 MW. Routine maintenance may, on occasion, take one of the electric chillers off-line, increasing CHP grid demand to approximately 1.0 MW. Ice storage offers significant benefits by allowing a dedicated 450 ton chiller to operate off-peak to charge storage, and discharge during the peak period.

Conclusion 2 Homeowner Energy Related Costs

There will be a modest reduction in the homeowner's direct energy costs based on current PG&E tariff levels and structures, mainly due to the lower effective tariff for heating and cooling derived from cogeneration. The gap in cost for the end user between traditional energy supply and an integrated approach will widen as primary fuel prices inevitably increase. Another major change will occur as California develops tariff structures that increase the cost of peak electric usage through real-time pricing or similar mechanisms. A further reduction in homeowner energy costs will be reduced maintenance costs, since the in-house energy delivery system is much simpler than current conventional practice.

Conclusion 3 Construction Cost

The cost to build the homes is slightly less than conventional construction, due to the elimination of individual furnaces, air conditioners and water heater, and their replacement by a relatively simple house service station connecting to the District Energy network. The cost comparison between conventional practice and the CHP service station is projected to result in $3,700 cost savings per single-family home.

Conclusion 4 Returns for the Village Energy System Operator

The investments for the District Energy system will be about $25 million for the central CHP plant, chillers and distribution network. The costs for the gas and electricity network that it replaces would be $11 million, indicating an incremental on-site investment of $14 million. However, the on-site investment allows upstream investments in electricity generation, transmission, and distribution to be avoided. Once the full benefits of avoided investments in the total system and some wider energy trading benefits are included, the returns for the Covell Village Energy System Operator are significantly better than for the PG&E system average. This indicates that PG&E would be a natural choice for system operator.

Conclusion 5 Ownership of the Energy System

The nature of District Energy systems is that the value increases as prevailing energy tariffs increase with time, the benefits of higher technical reliability accrue, and the system is supplying the fully built-out project. Recognising the limitations for PG&E to invest in an energy system of this type, and recognising the need for a no/low profit initial view of the investment to be feasible, the conclusion is that the energy system should be owned as a condominium asset of the entire Village.

Conclusion 6 Market Prices

Based on the energy related cost savings and other home owner benefits, NAHB data would suggest an average $5,000 price premium for each home, or about $8 million for the single family homes. The commercial property would also attract market premiums. However, assuming condominium ownership, the premium will be assigned to purchase of the energy system, and not to the developer as improved margin.

Conclusion 7 Climate Change Mitigation

With the utility generation model Covell Village would add 9,000 metric tons of carbon-dioxide to the atmosphere. In the District Energy scenario it would add less than 4,000 metric tons, even with no increase in building efficiency above the proposed 2005 Title 24 levels. This dramatically highlights the decoupling between greenhouse gas creations and building efficiency that is possible by the use of CHP. No financial value was assigned to this reduction, despite the fact that avoided carbon is trading in the Kyoto countries at up to $10 per metric ton[12], with expectations it will only go higher.

Conclusion 8 Renewable Energy

The benefits of CHP and the new Title 24 economically overwhelm any benefits from the two obvious sources of renewable energy – Solar Thermal and Solar Electric. The CHP plant is assumed to be fired from natural gas from the nearby transmission pipeline; however, a bio-gasification facility could be a source of part of the primary fuel. We were unable to quantify the economics of biogas facility in this study. It's attractiveness will depend on a number of issues including avoided land-fill costs, piping costs, etc.

Conclusion 9 Building Efficiency

Building homes to be more efficient than the 2005 California Title 24 Building Codes is not economically attractive when combined with District Energy. This is a result of the combination of the relatively benign climate in the Davis area, the relatively high efficiency implicit in Title 24, the fixed investment in the District Energy infrastructure, and the low cost of using heat to provide heating and cooling.

Conclusion 10 Wider Implications

The Covell Village analysis yields interesting societal, economic and environmental benefits. It is a medium density project, in a moderate climate, with highly efficient local building codes. In much of the rest of the USA, a similar development would frequently experience more humid summers and much colder winters (higher space conditioning loads), and would be built against codes that are at least 30% less efficient than Title 24. The energy and associated environmental benefits would be substantially greater just about anywhere else in the USA or Canada. As such, a project like Covell Village has the potential to be a national benchmark.

Recommendations

[12] Value of $54,800 per year with the project emission reduction of 5,480 metric tons. – see Point Carbon (www.pointcarbon.com) for weekly carbon trading rates

1. Covell Village should be positioned as a potential State Pilot Model development for residential District Energy and an Investment Grade Energy Master Plan should be completed.

2. Since California is the national leader in environmental and energy efficiency issues, the State should make the modest investment necessary to overcome the business and regulatory barriers for the developer and PG&E, and also ensure that the project financing does not act as a deterrent to the commercial success of the project.

3. PG&E should serve as the operator for the Covell Village CHP system.

4. Covell Village should be the cooperative owner of the energy assets. Alternatively, a public purpose entity should be formed to own the Covell Village energy assets strictly for demonstration purposes.

5. Other, similar projects should be evaluated, preferably with somewhat higher density. A current redevelopment project in Sacramento already under consideration is the Union Pacific Rail Yards, which will have construction density more than twice Covell Village.

6. Buildings in the Covell Village project should be built to a level of efficiency equal to Title 24. Exceeding Title 24 involves additional expense and reduces the cost effectiveness of the overall project. Projects in other states (with higher loads and less energy efficient construction practices) may generate different conclusions.

Public Benefits to California

The proposed Covell Village district energy project offers significant value to California by increasing awareness of the technology as a future sustainable development path. Education of government leaders, state energy managers, land use planners, developers, architects, and engineers contributes to increased awareness of such an advanced energy/development path. Most forward-thinking planners agree that the nature of future development must move towards a more sustainable model with a reduced environmental footprint and less reliance on the centralized utility grid model.

Specific sustainable development elements that this project addresses includes:

<u>Greater energy efficiency</u>. The proposed CHP design would result in a significant improvement in energy efficiency for the project relative to a conventional energy supply scenario.

<u>Reduced impact on electrical grid</u>. The proposed project would reduce summer peak electrical demand by 3 to 4 MW. This avoided load would contribute to increased grid

reliability and reduce the potential need for upgrading the existing transmission and distribution infrastructure.

Reduced environmental impact. The proposed project has significant environmental benefits include reduced air pollution and resultant global warming impacts. In addition, a CHP design is conducive to higher density development meaning smaller lots (more efficient land use and less area to be irrigated) and potentially smaller dwellings (less construction materials consumed).

Greater real estate affordability. Higher density construction implies smaller lots and smaller houses. Both of these factors contribute to lower home prices, increasing the affordability of the home.

Other benefits that can be realized include:

- A model to develop statewide community-scale integrated energy strategies that will bring into focus the advantages of integrated energy master planning for large construction projects.
- Opportunity to develop commercial expertise with growth and employment potential and out-of-state "expert" potential
    - Integrated Energy Master planning consultancy
    - Real estate development of super-efficient communities
    - Project management and construction skills for community-scale CHP designs
    - Develop a manufacturing and distribution supply chain for heat exchangers, piping systems, control technology, thermal metering etc.)
    - A clear demonstration that consumer satisfaction, commercial viability and breakthrough environmental performance are not incompatible.

The potential of district energy in California could be significant depending upon development trends in the next ten to twenty years. The district energy approach only makes sense in large master planned communities with a minimum project size comparable to Covell Village. The number of large developments appears to be increasing in recent years. We project that by 2020 the number of projects that fall in this category could by roughly 10% of the new homes built in California (from 15,000 to 25,000 homes). This estimate is highly speculative, but it indicates a significant potential for district energy in the state.

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Glossary

Absorption chiller: Chiller utilizing heat (hot water or steam) to dirve an absorption-desorption process without the requirement of large shaft work input

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers

Biogas: Fuel, produced of organic substances like green waste

CHP or Cogeneration: generation of power combined with use of engine (waste) heat

Compression chiller: Chiller operated with electricity as driving power

COP: Coefficient of Performance (efficiency descriptor for chillers)

Hydronic fan coil: An alternative to the conventional furnace and split system air conditioner. Utilizes a finned tube coil and an air handler to deliver space heating and cooling from a hydronic source (in this case the district heating and cooling network).

Ice storage: A reservoir for "building" ice during off-peak (night) hours and discharging cooling during on-peak (afternoon) hours. Although ice storage generally results in lower efficiency in providing cooling (due to lower evaporator temperatures), significant economic benefits can be derived by shifting electrical consumption from on- to off-peak periods. For a CHP system, an ice storage system is an effective way to utilize off-peak electrical generation.

LV: Low Voltage (electric service to households)

MICROPAS: An hourly computer simulation used to demonstrate compliance with the California Residential Building Energy Standards

NightBreeze: An integrated residential economizer that provides optimised summer night ventilation operation to a user specified comfort target

MV: Medium Voltage

O&M (or Operations and Maintenance): Costs associated with maintaining equipment, such as heating and cooling systems. For CHP systems, O&M is an essential part of achieving optimal system performance. Conventional HVAC equipment is rarely properly maintained. In many cases, this is acceptable, but it can lead to significant operational problems in certain situations.

Photovoltaic: Generation of electricity using silicon based cells under solar radiation

California Energy Commission Energy Innovations Small Grant (EISG) Program **PROJECT DEVELOPMENT STATUS**	**Questionnaire**

Please Identify yourself, and your project: **PI Name** : Berman **Grant** # 53420a/03-10

Overall Status

Questions	Comments:
1) Do you consider that this research project proved the feasibility of your concept?	*Yes. The project presents an optimized Combined Heat and Power system design for the Covell Village project.*
2) Do you intend to continue this development effort towards commercialization?	*Yes, if a public/private partnership can be formed.*
Engineering/Technical	
3) What are the key remaining technical or engineering obstacles that prevent product demonstration?	*No technical obstacles. Additional funding would provide for a formal design process for the project.*
4) Have you defined a development path from where you are to product demonstration?	*Yes. We are pursuing development and public commitments for this project and one similar to it.*
5) How many years are required to complete product development and demonstration?	*With funding, the Covell Village project would begin in 2007 given the current construction schedule from the developers.*
6) How much money is required to complete engineering development and demonstration?	*Approximately $1 million for engineering. Complete project implementation is estimated at $25 million.*
7) Do you have an engineering requirements specification for your potential product?	*N/a*
Marketing	
8) What market does your concept serve?	*The proposed project is directed towards large residentially-oriented development projects.*
9) What is the market need?	*Reduced peak electrical demand, reduced use of resources, and lower emissions and global warming impact.*
10) Have you surveyed potential customers for interest in your product?	*We worked with the Covell Village project developer in this study and are in discussions with the developer of the Sacramento Railyards project.*

11) Have you performed a market analysis that takes external factors into consideration?	*We have performed a preliminary assessment of legal/regulatory issues. Since this project is the "first of its kind", significant barriers need to be overcome once the decision is made to pursue the CHP approach. It is premature to expend resources at this stage to address those barriers.*
12) Have you identified any regulatory, institutional or legal barriers to product acceptance?	*YES. See final report.*
13) What is the size of the potential market in California for your proposed technology?	*For a separate proposal we completed an estimate of the California potential for CHP projects of this type. Based on current statewide construction rates, and a minimum project size of 500 homes, we estimated the current potential California market to be 30,000 homes and 30 CHP systems per year.*
14) Have you clearly identified the technology that can be patented?	*Nothing to be patented.*
15) Have you performed a patent search?	*N/a*
16) Have you applied for patents?	*N/a*
17) Have you secured any patents?	*N/a*
18) Have you published any paper or publicly disclosed your concept in any way that would limit your ability to seek patent protection?	*N/a*
Commercialization Path	
19) Can your organization commercialize your product without partnering with another organization?	*No. Significant public/private funding is needed.*
20) Has an industrial or commercial company expressed interest in helping you take your technology to the market?	*Yes. MVV Energie. They are a major international firm working in cogeneration and CHP.*
21) Have you developed a commercialization plan?	*Not formally.*
22) What are the commercialization risks?	*A wide range of barriers need to be addressed including project ownership, utility involvement, metering issues, etc. See final report for details.*
Financial Plan	

23) If you plan to continue development of your concept, do you have a plan for the required funding?	*We are in discussions with the developers of the Covell Village and Sacramento Railyards projects, and will present a request for additional funding to the CEC once developer commitment is in place.*
24) Have you identified funding requirements for each of the development and commercialization phases?	*Not in detail.*
25) Have you received any follow-on funding or commitments to fund the follow-on work to this grant?	*No.*
26) What are the go/no-go milestones in your commercialization plan?	*Developer commitment, additional government funding, possible enabling legislation.*
27) How would you assess the financial risk of bringing this product/service to the market?	*Significant risk without public support.*
28) Have you developed a comprehensive business plan that incorporates the information requested in this questionnaire?	*No.*
Public Benefits	
29) What sectors will receive the greatest benefits as a result of your concept?	*Environmental advantages and energy efficiency are the primary benefits. The power sector will benefit by improved supply security and avoided network and generation facility extension costs.*
30) Identify the relevant savings to California in terms of kWh, cost, reliability, safety, environment etc.	*Documented in the final report.*
31) Does the proposed technology reduce emissions from power generation?	*Yes. Once the project is fully built out we estimate reductions of 5,480 metric tons of CO_2, 3280 lbs of SO_2, and 10770 lbs of NO_x . See final report for details.*
32) Are there any potential negative effects from the application of this technology with regard to public safety, environment etc.?	*Although the air quality benefits are significant, the source of the emissions will be local instead of from a remote site..*
Competitive Analysis	
33) What are the comparative advantages of your product (compared to your competition) and how relevant are they to your customers?	*The primary benefits are societal, not to individual customers. The top 3 are air quality, energy conservation, and sustainable development.*
34) What are the comparative disadvantages of your product (compared to your competition) and how relevant are they to your customers?	*Use of CHP in residential developments requires developers and builders to do something"different", and will require a commitment of organizational time. Most businessmen are reluctant to make changes of this nature.*
Development Assistance	
The EISG Program may in the future provide follow-on services to selected Awardees that would assist them in obtaining follow-on funding from the full range of funding sources (i.e. Partners, PIER, NSF, SBIR, DOE etc.). The types of services offered could include: (1) intellectual property assessment; (2) market assessment; (3) business plan development etc.	

35) If selected, would you be interested in receiving development assistance?	*Yes.*

Appendices

Appendix A: CHP System Design Schematics

Appendix B: Input Load Data for CHP Design Model

Appendix C: Design Model Inputs and Outputs

Appendix D: Preliminary Legal Issues Review